Nature of Photon

Ilgaitis Prūsis[1,] Peteris Prūsis[2]

Abstract

It is well known that the photon is only a quanta of electromagnetic radiation. However, there are many myths around the photon in contemporary physics, for example, the photon loses energy when traveling through space. The article explains the basic features of the photon, such as wave-particle duality, the relation between a continuous electromagnetic wave and a quanta, the interaction of electric and magnetic fields, space of photon, speed of light.

Keywords: Quantum mechanics, energy, EM wave, space, gravitation, Unified Field Theory, electric field, magnetic field, conservation of energy, General physics, particle physics, philosophy of science

PACS Classification codes:

01.55.+b General physics; 04. General relativity and gravitation; 03.50.-z Classical field theories; 12.10.-g Unified field theories and models

Introduction

Photon, also called **light quantum**, minute energy packet of electromagnetic radiation. The concept originated (1905) in Albert Einstein's explanation of the photoelectric effect, in which he proposed the existence of discrete energy packets during the transmission of light. Earlier (1900), the German physicist Max Planck had

[1] Independent researcher;
[2] Independent researcher

prepared the way for the concept by explaining that heat radiation is emitted and absorbed in distinct units, or quanta [1]. End of quotation.

Electromagnetic field

The set of Maxwell equations [2] for vacuum is:

$$rot\,\boldsymbol{E} = -\,1/c\;\partial \boldsymbol{B}/\partial t, \qquad (1)$$
$$rot\,\boldsymbol{B} = 1/c\;\partial \boldsymbol{E}/\partial t, \qquad (2)$$
$$div\,\boldsymbol{E} = 0 \qquad (3)$$
$$div\,\boldsymbol{B} = 0 \qquad (4)$$

where: ***E*** – vector of electric field,
B – vector of magnetic field,
t – time,
c – speed of light.

In the case of a monochromatic wave the expression for electric field ***E*** is:

$$\boldsymbol{E}\,(x, t) = \boldsymbol{E}_0 \sin(\omega t), \qquad (5)$$

where: $\boldsymbol{E}_0$ – amplitude of electric field.

A physically correct solution can be obtained if in the equation (2) the expression of electric field ***E*** is used from (5), i.e., $rot\,\boldsymbol{B} = 1/c\;\partial(\boldsymbol{E}_0 \sin(\omega t))\,/\partial t.$

The result is: $\boldsymbol{B}\,(x, t) = \boldsymbol{B}_0 \cos(\omega t).$ (6)

Vector ***E*** is shifted according to vector ***B*** by 90 degrees (Fig. 1.).

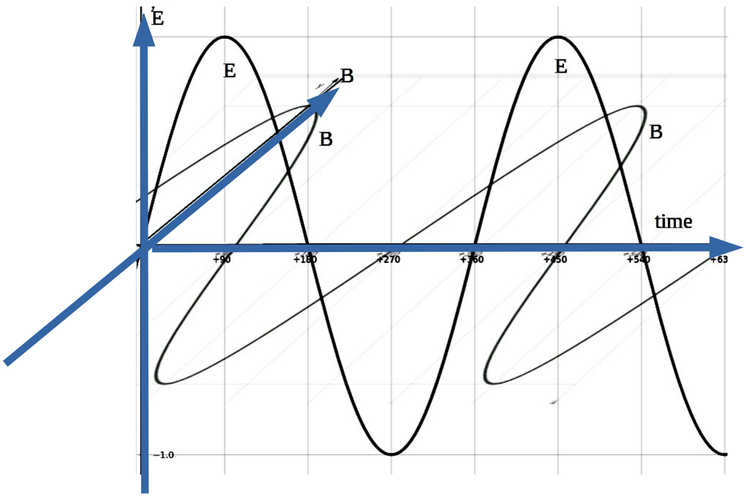

Fig. 1. Electric ***E*** and magnetic ***B*** field of photon.

Sometimes the equation system (1….4) is solved independently, i.e., for the electric field the equations (1 and 3) and for the magnetic field the equations (2 and 4) are used. Mathematically the above-mentioned is correct. From the physical point of view it is nonsense because it violates the energy conservation law [3].

Space of Photon

The space equation [4] is a basic equation for any physical force field:

$$\alpha/\Pi = r^2 I\,, \qquad (7)$$

where: α – source of field,
Π – propagation of field,
r – distance,
I – intensity.

To describe space of any physical force field it is necessary to know only the source of the field, its propagation and intensity. For vector fields the source is a vector-potential.

The photon has two vector potentials: $\varphi E = rot\ H$ and $\varphi H = -\ rot\ E$. Propagation is: $\Pi_E = 4\pi\varepsilon_0$ for electric field and $\Pi_M = 4\pi\mu_0$ for magnetic field.

Therefore the space of the photon describes the system of equations:

$$\begin{cases} 4\pi\ r^2 \vec{E} = \dfrac{W}{\varepsilon_0\ rot\ \vec{H}} \\ 4\pi\ r^2 \vec{H} = \dfrac{W}{\mu_0\ rot\ \vec{E}} \end{cases} \qquad (8)$$

The energy of photon: $W = h\upsilon$ (9)

where: h – Planck constant,
υ – frequency of photon.

For this reason, the photon has two dimensional electric space and two dimensional magnetic space. Both spaces are orthogonal to each other. The total dimensionality of the photon is four. In gravity (conventional) space the photon is a wave with speed *c*, which depends on the propagation of magnetic and electric fields in the media: $c^2 = \varepsilon\mu$.

In its own electromagnetic space the photon is a particle. The above-mentioned is the cause of photon wave-particle duality.

Electromagnetic (EM) waves and quanta

The photon is the quanta of an electromagnetic wave. It is worth trying to determine the number of photons in the signal of a cellular phone during communication. The power of the signal is in the range from 1 mW in the vicinity to 3W far from the station. Normally the phone emits about 60mW of electromagnetic radiation. The frequency of the signal is in the range from 0.4 to 5GHz. The 0.9 GHz frequency is most commonly used. The energy of the photon (9) is:

$W = h\upsilon = 6.626\ 10^{-34} * 9\ 10^{8} = 59.6\ 10^{-26}$ J

Thus 59.6 mW of the electromagnetic wave contains $59.6\ 10^{-3}$ / $59.6\ 10^{-26} = 10^{23}$ quanta (photons) each second. The photons in the electromagnetic wave have a quantum entangled status. They are entangled electrically, magnetically and in time.

EM wave and loss of energy

An EM wave can lose energy only by reducing the magnitude of electric and magnetic field. It means that the number of photons is reduced. The frequency remains unchangeable. Therefore the energy of an individual EM quanta remains constant according to the equation (9). There is no experimental or theoretical evidence that the frequency of EM wave can change while traveling through space.

Frequency can only change if the photon is absorbed by an atom, which is followed by the emission of several photons with lower energy. For this reason, primordial hot photons cannot lose energy and cool dawn while traveling in space.

Speed of light

Light is only electromagnetic radiation. The constancy of speed of light is only a presumption. In reality, speed of light is dependent on electric and magnetic field propagation in the media: $c^2 = \varepsilon\mu$. In the meta materials [5] the speed of light can be in the wide range of values from zero to numbers that many times exceed the speed in vacuum. The speed of light in the vacuum depends on the density of interstellar medium. The Universe expands. Therefore, earlier the density of interstellar medium (vacuum) was higher than now and the speed of light was different. It can be assumed that the density of the Universe and the speed of light does not change significantly only in relatively short periods of time.

References

1. *Encyclopædia Britannica* https://www.britannica.com/science/photon

2. Feynman, R. Solutions of Maxwell's Equations in Free Space. http://www.feynmanlectures.caltech.edu/II_20.html

3. Prūsis I. and Prūsis P. About Energy of Photon. https://ia601507.us.archive.org/21/items/AboutEnergyOfPhoton/About%20Energy%20of%20Photon.pdf

4. Prūsis I. and Prūsis P. New Concept of Space. https://ia601501.us.archive.org/21/items/NewConceptOfSpace/New%20concept%20of%20Space%20v2.pdf

5. Withayachumnankul et al. A Systemized View of Superluminal Wave Propagation. Proceedings of the IEEE 0018-9219. (2010).

Acknowledgements: We are very grateful to Ieva Mazere and Valda Kalniņa for valuable discussions and assistance.

Correspondence and requests for materials should be addressed to I.P. (ilgaitis@gmail.com).